PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.:	10/771,692
Filing Date:	February 4, 2004
Applicant:	PARK, Edward H. et al.
Group Art Unit:	3673
Examiner:	Alison K. Pickard
Title:	Dynamic Seal Using Vulcanization of Fluorocarbon Elastomers
Attorney Docket:	03-0052 (8470-000016)

DECLARATION UNDER 37 C.F.R. § 1.131

PURPOSE OF DECLARATION

1. We are the inventors who made application for a patent on February 4, 2004 having the subject matter described and claimed therein, including Claims 1 through 30.

2. This declaration is being presented to establish conception and reduction to practice of the invention of our above identified patent application in the United States at a date prior to July 15, 2003, the filing date of U.S. Pat. No. 7,022,769.

FACTS AND DOCUMENTARY EVIDENCE

3. The conception and reduction to practice of our invention in the United States is evidenced by the notebook pages, interim report, and Invention Disclosure Form attached hereto at Exhibit A through Exhibit F. These pages are true copies of the original documents or

electronic files. All copies of notebook pages are from the supporting lab notebook(s) kept by Edward Park in the normal course of business. As indicated below, any redacted portions of the Exhibits either disclose dates that are prior to July 15, 2003, dates that are shortly after July 15, 2003, or disclose personal or confidential client information.

4. Prior to July 15, 2003, our invention was conceived and reduced to practice in the United States and experiments were conducted to generate the data detailed in Exhibit A through Exhibit F.

5. The notebook pages provided at Exhibit A evidence various formulations of fluorocarbon elastomers used in accordance with the teachings of the present invention. The redacted portions of Exhibit A either disclose dates prior to July 15, 2003 or personal or confidential client information.

6. The work order provided at Exhibit B evidences that having earlier conceived of the concept of the present invention, we requested various material development testing to generate data concerning the seals of the present invention. The redacted portions of Exhibit B either disclose dates prior to July 15, 2003 or personal or confidential client information.

7. The notebook pages provided at Exhibit C evidence reduction to practice, experimental data, and improvements in the design of the present invention. The redacted portions of Exhibit C either disclose dates prior to July 15, 2003 or personal or confidential client information.

8. The notebook pages provided at Exhibit D evidence ongoing experimental data and long-term testing of the present invention. The redacted portions of Exhibit D either disclose dates shortly after July 15, 2003 or personal or confidential client information.

9. The Interim Report provided at Exhibit E evidences a summary of the previous testing concerning the present invention. The redacted portions of Exhibit E either disclose dates shortly after July 15, 2003 or personal or confidential client information.

10. The conception and reduction to practice of our invention in the United States is further evidenced by the written description attached at Exhibit F. These pages were taken from an Invention Disclosure Form that summarizes the previous findings and data concerning the invention of the pending patent application. The redacted portions of Exhibit F either disclose dates that are prior to July 15, 2003, or are shortly after.

DECLARATION

Each of the undersigned hereby declares that the statements made herein are of his own knowledge and true and that any statement made on information and belief is believed to be true; and further that these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statement may jeopardize the validity of the application, and any patent issuing thereon, on his patent to which this declaration is directed.

Edward Hosung Park	August 17, 2006 Date
Alexander Berdichevsky	8/17/06 Date
Vahidin Alajbegovic	8/17/06 Date

[redacted] tech 2 No.3252 P. 3

PROJECT NAME Fluoroprene TPV NOTEBOOK NO.

formulation PCC536-131A without wear package

REDACTED

Ed Park Ed Park

Material Development - Formulation and Mixing Detail
3.0L Moriyama Mixer

Chemist of Record: Ed Park
Work Order Number: 1804-021038
Lab Book: PCC550
Objective(s): FKM-TPV
Compound Number: PCC550-001

Date: [redacted]
Lead Center Code: 6317
Project Number:
Cure Time:
Post Cure:

Item #	Type	Ingredient	Lot No.	Total g	A pphr	A g	B pphr	B g	C pphr	C g	D pphr	D g	E pphr	E g
1		Dyneon FE5640			70.0	1611.5	70.0	146.2	70.0	138.7	70.0	118.8	70.0	120.2
2		Dyneon BRE 7231X			30.0	690.7	30.0	62.7	30.0	59.6	30.0	66.2	30.0	51.5
3		Dyneon THV 815X			75.0	1726.8	75.0	165.7	75.0	148.6	75.0	138.0	75.0	128.8
4		FKM Regrind PA814			50.0	1151.2			10.0	19.8	25.0	46.0	40.0	68.7
5		Rhenofit CF			6.0	138.1	6.0	12.5	6.0	11.9	6.0	11.0	6.0	10.3
6		Elastomag 170			3.0	69.1	3.0	6.3	3.0	5.9	3.0	5.5	3.0	5.2
7		Kamenite 5221			1.0	23.0	1.0	2.1	1.0	2.0	1.0	1.8	1.0	1.7
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
		Sp. Gr.			1.84		1.84		1.84		1.84		1.84	
		Fill Factor			0.70		0.05		0.05		0.05		0.05	
	Total FW				235.0	5410.5	185.0	384.8	195.0	386.5	210.0	384.6	225.0	386.6

Mixing Instructions

Addition Order			Time	Temp C	Comments
1					Batches 8 CCE rebuilt on Stationary
2					
3					
4					
5					
6					
7					
8					

FM-10-TECH-035 Rev 1

Ed Park Ed Park

SIGNATURE Edward N. Park DATE [redacted]
READ AND UNDERSTOOD DATE 20

4

PROJECT NAME Fluoroprene TPU NOTEBOOK NO.

Formulation with glass spheres.

REDACTED

Ed Park

Ed Park

Material Development - Formulation and Mixing Detail
Banbury Mixer

Chemist of Record: Ed Park
Work Order Number: 3304-031093
Lab Book: PCC640
Objective(s): FKM-TPV
Compound Number: PCC483-084

Date: [redacted]
Lead Center Code: 6317
Project Number:
Cure Time:
Post Cure :

Item #	Type	Ingredient	Lot No.	Total g	A pphr	A g	B pphr	B g	C pphr	C g	D pphr	D g	E pphr	E g
1		Dyneon FE5840			70.0	128.8	70.0	125.8	70.0	123.0	70.0	120.2	70.0	117.6
2		Dyneon BRE 7231X			30.0	56.2	30.0	53.9	30.0	53.7	30.0	51.6	30.0	50.4
3		Dyneon THV 815X			75.0	130.0	75.0	134.6	75.0	131.7	75.3	128.8	75.0	126.0
4		Glass Spheres 3000E			5.0	9.2	10.0	18.0	15.0	26.3	20.0	34.4	25.0	42.0
5		Rhenofit CF			6.0	11.0	6.0	10.8	6.0	10.6	6.0	10.3	6.0	10.1
6		Elastomag 170			3.0	6.5	3.0	5.4	3.0	5.3	3.0	5.2	3.0	5.0
7		Kemamide 8221			1.0	1.8	1.0	1.8	1.0	1.8	1.0	1.7	1.0	1.7
8		Austin Black			20.00	36.8	20.00	36.0	20.00	35.1	20.00	34.4	20.00	33.6
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
		Sp. Gr			1.84		1.84		1.84		1.84		1.84	
		FM Factor			0.05		0.05		0.05		0.05		0.05	
	Total FW				210.0	386.6	215.0	386.6	220.0	386.6	225.0	386.6	230.0	386.8

Mixing Instructions

Addition Order				Time	Temp C	Comments
1						[illegible]
2						
3						
4						
5						
6						
7						
8						

Rev 1

FM-13-TECH-083

Ed Park

Ed Park

SIGNATURE Edward A. Park DATE [redacted]
READ AND UNDERSTOOD DATE / 20

PROJECT NAME Fluoroprene TPV. NOTEBOOK NO.

Formulation with different ratio of elastomer and plastics.

REDACTED

Material Development - Formulation and Mixing Detail
Brabender Twin Screw Mixer

Chemist of Record: Ed Park
Work Order Number: 2304-021003
Lab Book: PCC650
Objective(s): FKM-TPV
Compound Number: PCC650-006

Date: [redacted]
Lead Center Code: 6317
Project Number:
Cure Time:
Post Cure :

Item #	Type	Ingredient	Lot No.	Total g	A pphr	A g	B pphr	B g	C pphr	C g	D pphr	D g	E pphr	E g
1		Dyneon FE5840			70.0	186.6	70.0	159.1	70.0	123.0	70.0	100.2	70.0	84.5
2		Dyneon BRE 7231X			30.0	80.0	30.0	68.2	30.0	52.7	30.0	42.9	30.0	36.2
3		Dyneon THV 815X			25.0	66.6	50.0	113.7	100.0	175.7	150.0	214.7	200.0	241.5
4		Rhenofit CF (Ca(OH)2)			6.0	16.0	6.0	13.6	6.0	10.5	6.0	8.6	6.0	7.2
5		Elastomag 170 MgO			3.0	8.0	3.0	6.8	3.0	5.3	3.0	4.3	3.0	3.6
6		Kemamide 6221			1.0	2.7	1.0	2.3	1.0	1.8	1.0	1.4	1.0	1.2
7		Austin Black			10.00	26.7	10.00	22.7	10.00	17.8	10.00	14.3	10.00	12.1
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
		Sp. Gr.			1.84		1.84		1.84		1.84		1.84	
		Fill Factor			0.05		0.05		0.05		0.05		0.05	
	Total FW				145.0	386.6	170.0	386.6	220.0	386.6	270.0	386.6	320.0	386.6

Mixing Instructions

Addition Order				Time	Temp C	Comments
1						Batches BCDE mixed on Brabender
2						
3						
4						
5						
6						
7						
8						

FM-10-TECH-035

Rev: 1

SIGNATURE DATE [redacted]
READ AND UNDERSTOOD DATE / 20

PROJECT NAME New fluoroprene for I.M. NOTEBOOK NO.

New fluoroprene formulations for I.M. (i.e. [redacted] shaft seal).

REDACTED

Ed Park

242 AA. AAA

Material Development - Formulation and Mixing Detail
3.0L Moriyama Mixer

Chemist of Record: Ed Park
Work Order Number:
Lab Book: PCC650
Objective(s): FKM-TPV
Compound Number: PCC650-150

Date: [redacted]
Lead Center Code: 6317
Project Number:
Cure Time:
Post Cure :

Item #	Type	Ingredient	Lot No.	Total g	A pphr	A g	B pphr	B g	C pphr	C g	D pphr	D g	E pphr	E g
1		Dyneon FE5840			70.0	2594.1	70.0	2594.1					70	
2		Dyneon BRE 7231X			30.0	1111.8	30.0	1111.8					30	
3		Viton F605C							100.0	3705.8	100.0	3705.8		
4		Ausimont Hylar MP-10			25.0	926.5			25.0	926.5				
5		Ausimont Halar 500 LC					25.0	926.5			25.0	926.5	50	
6		Rhenofit CF			6.0	222.4	6.0	222.4	6.0	222.4	6.0	222.4	6	
7		Elastomag 170			3.0	111.2	3.0	111.2	3.0	111.2	3.0	111.2	3	
8		Struktol WS-280			1.0	37.1	1.0	37.1	1.0	37.1	1.0	37.1	1	
9		Austin Black			10.00	370.6	10.00	370.6	10.00	370.6	10.00	370.6	10	
10		Technoflon FPA-1			1.00	37.1	1.00	37.1	1.00	37.1	1.00	37.1	1	
11														#DIV/0!
12														#DIV/0!
13														#DIV/0!
14														#DIV/0!
15														#DIV/0!
16														#DIV/0!
17														#DIV/0!
														#DIV/0!
														#DIV/0!
		Sp. Gr.			1.84		1.84		1.84		1.84		1.84	
		Fill Factor			0.70		0.7		0.7		0.7		0.05	
	Total FW				146.0	5410.6	146.0	5410.6	146.0	5410.6	146.0	5410.5		#DIV/0!

Mixing Instructions

Addition Order				Time	Temp C	Comments
1						Batches ABCD mixed on Moriyama
2						
3						
4						
5						
6						
7						
8						

FM-10-TECH-035

Rev: 1

Ed Park

SIGNATURE Ed Park DATE [redacted]
READ AND UNDERSTOOD DATE 20

Plymouth-Home Quickjump

Printer friendly view

3013-030421

[redacted]Seal Test

Project Name:	[redacted]Seal Test		
Work Order #:	3013-030421	**PATTH #**	

Lead Center Location Code	PLY - Material Development - 6317	**Requestor's Name**	David Barth
Requested Start Date	[redacted]	**Requestor's Phone Number**	734.354.5377
Requested Completion Date	[redacted]	**Primary Investigator**	Cory Johnson
Promised Completion Date	[redacted]	**Chemist of Record**	N/A
Work Type	M	**Report Copy List**	CAM@FNGP.COM
Material Family			
Completion Status	COMPLETE [redacted]	Update Completion Status	

	Statement of Work
Test [redacted] Seal provided per [redacted] test procedure Cory - Please see Chris Mains for advise and training on setting up the test.	
X	The supplied samples or components are not customer owned.
X	The use of overtime is not warranted.
	Disposition of samples:
	The work will be completed by the Mechanical Lab.

Hours logged for the project = 155 hrs.

Comments by the Investigator

REDACTED

Date	[redacted]
Description	
Hours	0.25
Hours Type	Regular Hours
Category	Chemist
	Update Comments

Reports

Printer friendly view

PROJECT NAME FKM-TPV RSS. NOTEBOOK NO.

FKM-TPV material formulations were developed for [redacted] type Radial Shaft Seal (RSS).

REDACTED

Edward Park
[redacted] 10:02 AM

To: Ted Duclos/Plym/North/FNGP@FNGP
Subject: [redacted] Shaft Seal Test with New Injection Molding Grade Fluoroprenes

Ted,

FYI

Edward Park
—— Forwarded by Edward Park/Plym/North/FNGP on [redacted] 10:01 AM ——

Edward Park
[redacted] 10:00 AM

To: Cory Johnson/Plym/North/FNGP@FNGP, James Bronersky/Plym/North/FNGP@FNGP
cc: Joe Walker/Plym/North/FNGP@FNGP
Subject: [redacted] Shaft Seal Test with New Injection Molding Grade Fluoroprenes

Cory and Jim,

As we discussed this morning, I understand that [redacted] shaft seal made with 006-B series (B, BB and BBB: ~ 86 Shore A) new Fluoroprene formulations performed better than 006-A series (A, AA and AAA: ~ 79 Shore A) formulations for our in-house shaft seal test. Shaft seal with 006-B formulation did not show any sign of leak during 9 hours of first cycle (24 hours per cycle; see below for detailed test steps), which is better than shaft seal with three 006-A series materials (most of them leaked within 2 hours of first cycle). We found a sign of leak this morning, when the test is already in second repeat cycle. Unfortunately, we are not sure when the leak was occurred during the overnight run. In the future, we may need some sort of monitoring device, such as time lap video recording device, to detect the moment of leak during the overnight run.

Beyond new material development effort, we need a proper shaft seal design, for example, the location of radial spring to provide a right amount of radial force to the proper location of shaft seal, which is mentioned by Dave Sakata. I understand that a design and fabrication of modified shaft seal mold insert is in progress. Cory and Jim, please continue on shaft seal test for two remaining shaft seals with 006-BB and 006-BBB formulations.

Edward Park

* Shaft Seal Test *

Rear Pinion (M80) Test - 4 seals/40 cycles each

1.	Dynamic CCW	1 min.	180oF	500 rpm
2.	Dynamic CW	2 hrs.	225oF	2000 rpm
3.	Dynamic CW	16 hrs.	225oF	4600 rpm
4.	Dynamic CW	1hr. 59 min.	275oF	3000 rpm
5.	Static	4 hrs.	No Heat	—

Ed Park

Ed Park

SIGNATURE Edward Ho-Jun Park DATE [redacted]
READ AND UNDERSTOOD DATE

REDACTED

PROJECT NAME EKM-TPU RSS

pre heat-treatment before radial shaft seal test implemented to extend the life of RSS, which faces up to 275°F during the test cycle. The plastic nature of EKM-TPU is caused for shrinkage and expansion of shaft seal material during the test cycle. Pre heat-treatment process was applied to release the residual stress during the injection molding process. The quench solidification of molten plastics in the cold mold at the high pressure generate frozen residual stress during the injection molding process. The release of frozen residual stress before the RSS test is necessary to minimize the dimensional fluctuation during the elevated temperature cycle. EKM-TPU based RSS are pre heat-treated at 125°C and 150°C.

SIGNATURE [illegible] DATE [redacted]

READ AND UNDERSTOOD DATE 20

[redacted]

REDACTED

PROJECT NAME FKM-TPU RSS. NOTEBOOK NO.

FKM-TPU based RSSs were tested after heat-treatment. Heat-treatment is required to stabilize the dimensional fluctuation due to shrinkage of FKM-TP

Edward Park
[redacted] 10:41 AM

To: Joe Walker/Plym/North/FNGP@FNGP
Subject: FKM-TPV [redacted] Radial Shaft Seal (RSS) Test

Joe,

I would like to let you know that our RSS test is currently 3rd cycle without a sign of any leaks. The test protocol attached below for your information. As I mentioned, these RSSs were molded with new injection molding grades of FKM-TPV formulations and heat-treated (annealed) at 300oF (150oC) to eliminate shrinkage during the repeated high and low temperature cycle. It looks like this approach is working well at this moment. We will mold more RSSs and heat-treat them to confirm the repeatability.

We also received five extrusion grades of FKM-TPVs (about 50 lbs each) from outside contract compounder [redacted] We will confirm the extrudability of these compounds with internal tube extrusion trial and send a couple of best performing grades to [redacted] for their fuel hose extrusion trial.

I and Dave visited [redacted] They have so-called "MeltFlipper" technology, which could help to achieve the flow balance for multi-cavity mold. They claimed that temperature build-up at the runner surface with the high speed injection operation could reached 100 ~ 200oF higher than the center of the runner. This behavior maybe closely related for our rubber injection molding operation, which we are trying to confirm high temperature generation at the high shear rate with our current rheological study. By the way, I completed the shear viscosity measurement as a function of temperature for three rubbers (FKM, ACM and Silicone). I am still waiting for new die set to measure the shear viscosity as a function of high shear rate (up to 7,000 1/S).

We also visited [redacted] to discuss the adhesive development for our FKM-TPV materials. They had two new adhesive formulations, and they molded adhesive coated coupons with FKM-TPV we supplied in front of us. We could not find out the effectiveness of these adhesives at that time, since it required 24 hours waiting period before testing. We met several key chemists and managers for this project, and we decided to have more frequent contacts each other to inform new adhesive and FKM-TPV development, respectively.

Edward Park

* Shaft Seal Test *

Rear Pinion (M80) Test - 4 seals/40 cycles each

1. Dynamic CCW	1 min.	180oF	500 rpm
2. Dynamic CW	2 hrs.	225oF	2000 rpm
3. Dynamic CW	16 hrs.	225oF	4600 rpm
4. Dynamic CW	1hr. 59 min.	275oF	3000 rpm
5. Static	4 hrs.	No Heat	—

SIGNATURE Edward H. Park DATE [redacted]
READ AND UNDERSTOOD DATE

REDACTED

PROJECT NAME FKM - TPU RSS NOTEBOOK NO.

FKM - TPU based RSSs were tested to evaluate the pre-heat treated FKM-TPU materials for RSS performance

Edward Park
[redacted] 11:37 AM

To: fjw@fngp.com
Subject: Fluoroprene [redacted] RSS Test

Joe,

As we discussed, the longest time we had with Fluoroprene [redacted] radialshaft seal (RSS) was 69 hours so far. New Fluoroprene formulations and pre-heat treatment of molded RSS was major steps to improve the performance of Fluoroprene RSS. For the next step, we should consider the differences between conventional elastomer RSS and Fluoroprene RSS, such as thermoplastic nature of Fluoroprene, material shrinkage, radial spring force, lip location against the position of radial spring load, contact area and shape (contour) of lip, surface texture of lip (number of asperities), molecular orientation of Fluoroprene material due to mold flow design during injection molding operation, application of various helix structure in the seal, etc. I think you could get some help from new seal engineer, Al Alajbegovic, to modifiy current RSS design to accomodate Fluoroprene material. The various measurements of Fluoroprene RSS before and after test are attached for your information.

Edward Park

Data set # [redacted] RSS 0803M

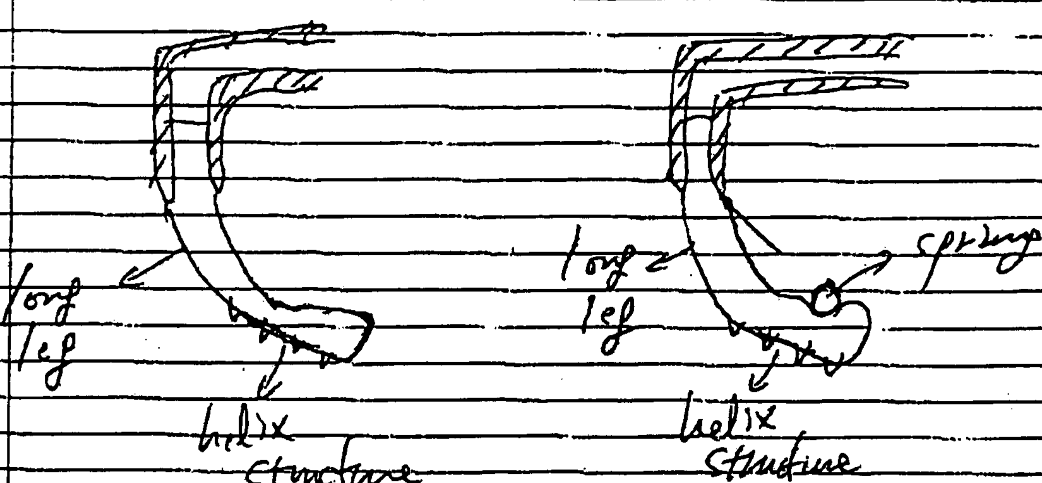
Sample	Material	Post Cure	Pre-test Conditions			Post-test Conditions			Time
#			ID	Load	w/spring	ID	Load	w/spring	Failed
1	PCC550-150B	125 C	62.1	35.0	47.0	63.5	0.0	0.0	27.3hrs
2	PCC550-150A	125 C	62.6	25.0	40.0	63.3	0.0	1.8	20.3hrs
3	PCC550-150B	150 C	62.7	40.0	65.0	63.4	2.0	4.0	2.3hrs
4	PCC550-150A	150 C	63.2	15.0	23.0	63.4	2.3	4.5	69.0hrs
5	PCC550-150B	150 C w/center	N/A	65.0	65.0	63.4	3.0	8.1	2.2hrs
6	PCC550-150B	150 C w/center	N/A	85.0	85.0	63.3	3.0	16.0	19.5hrs
7	PCC550-150A	150 C w/center	N/A	50.0	55.0	63.4	1.6	2.2	43.1hrs
8	PCC550-150A	150 C w/center	N/A	40.0	51.0	63.6	0.0	0.0	43.1hrs

SIGNATURE Edward Park DATE [redacted]
READ AND UNDERSTOOD DATE 20

PROJECT NAME TPE based Dynamic Seals NOTEBOOK NO.

REDACTED

Hybrid Seal designs are proposed for TPE type material. Initially, FKM-TPU type TPE materials are major interest to develop dynamic seals to accommodate the properties of FKM-TPU (Fluoroprene®) type materials. Hybrid seal designs are the combination of typical commercial seal design for elastomer (rubber) and PTFE plastic materials, since the properties of TPE type materials are the mixture of elastomer and PTFE plastic material properties. The proposal seal designs are as follows;



Seal Trend

SIGNATURE [signature] DATE [redacted]
READ AND UNDERSTOOD DATE 20

[redacted]

REDACTED

Freudenberg-NOK
Plymouth Technology Center
Dynamic sealing R&D
47690 E. Anchor Court
Plymouth, MI 48170

[redacted]

Fluoroprene™ [redacted] Radial Shaft Seal Test
-Interim Report-

In order to better understand Fluoroprene™ material in a dynamic sealing application, [redacted] seal design used was to explore the potential use of the new material in some of the current sealing applications. [redacted] RSS [redacted] originally uses FKM (VG705) as the sealing material. Fluoroprene™ was used as a direct replacement. 38 seals were injection molded in the existing test mold. Three Fluoroprene™ formulations were used: PCC550-150A (basic), PCC550-150AA (addition of wear package) and PCC550-150AAA (with no carbon black). In absence of an adequate adhesive, 64 holes were drilled in the metal case to allow for mechanical bond between the elastomer and the metal case. Heat treatment was performed on the seals to allow for stress relaxation. Previous experiments showed strong influence of thermal cycling on the elastomer shape and sealing capability. 22 seals were heat treated before trimming the lip and 16 seals were trimmed first and then heat treated. Heat treatment consisted of keeping the seals for 16 hours in an oven at 150°C. Additional heat treatment of 4 hours at 150°C was performed on the seals that were originally first heat treated and then trimmed.

The seals which were heat treated first exhibited the deformation as shown in Figure 1. Material shrinkage in the center cap pulled the seal lip inward. This presented a problem for trimming operation due to change in geometry of the lip. Approach angle of the trimming knife was modified to produce correctly trimmed lip. This deformation of the lip also affects the R-value (distance between the lip contact and the center of the spring). Too much deformation can create a negative R-value, which is not acceptable.

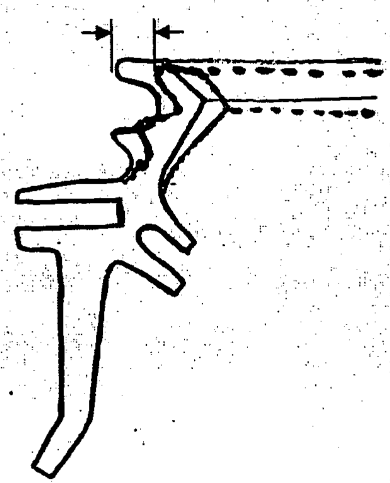


Figure 1: Sketch of Lip Deformation after Initial Heat Treatment

An additional deformation was observed on the dust lip. It is suspected that small differences in the material density and flow pattern in the mold become visible after heat treatment, thus forming an uneven lip as shown in Figure 2.

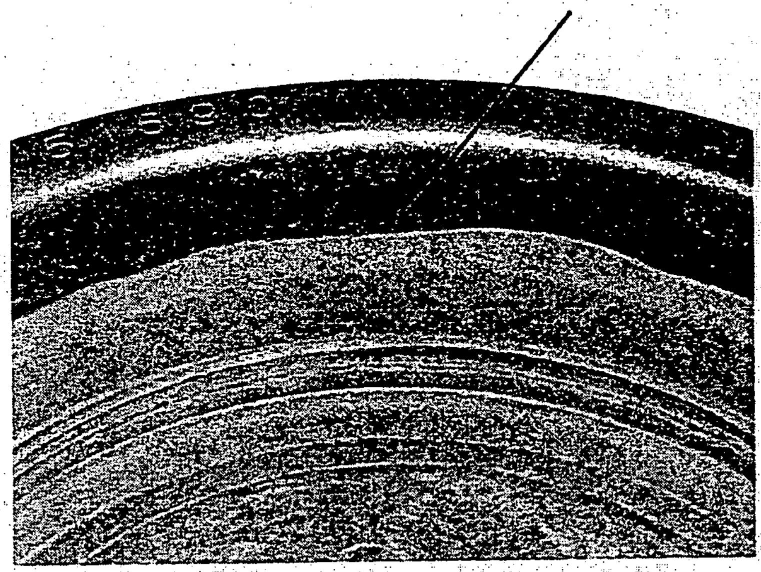


Figure 2: Dust Lip Deformation after Heat Treatment

Final seal lip internal diameters were measured on the OGP. This data is shown in Figure 3. Red color is used for seals molded from PCC550-150A (basic formulation), Blue for PCC550-150AA (addition of wear package) and magenta for PCC550-150AAA (with no carbon black). Squares represent the seals that were first trimmed and then heat treated. Circles represent the seals that were heat treated first, then trimmed and heat treated again. Second heat treatment was necessary to ensure lip achieve stable final dimension.

Several rational subgroups can be derived from the plot.

First group are the seals shown in squares (trim – heat treatment). These seals from all three materials show good dimensional correlation. Mean ID is 64.81 and standard deviation is 0.133.

Second group are the seals shown in red circles (material 150A, heat treated-trimmed-heat treated). The ID is scattered over a much larger range (1.54mm) partly due to difficulty to trim the deformed lip accurately and partly due to compounded error accumulated in the multi staged process (two heat treatments). Mean value for this group is 63.57mm and standard deviation is 0.481.

Third group are the seals shown in blue circles (material 150AA, treated-trimmed-heat treated). This group of seals has low scatter even it had same treatment as the second group. Apparently, material PCC550-150AA (with addition of wear package) exhibits very good dimensional stability. The mean is 63.68 and standard deviation is 0.155.

Fourth group of seals (shown in magenta circles) exhibits similar behavior as seals from the second group. The mean value is 63.78mm and standard deviation is 0.477.

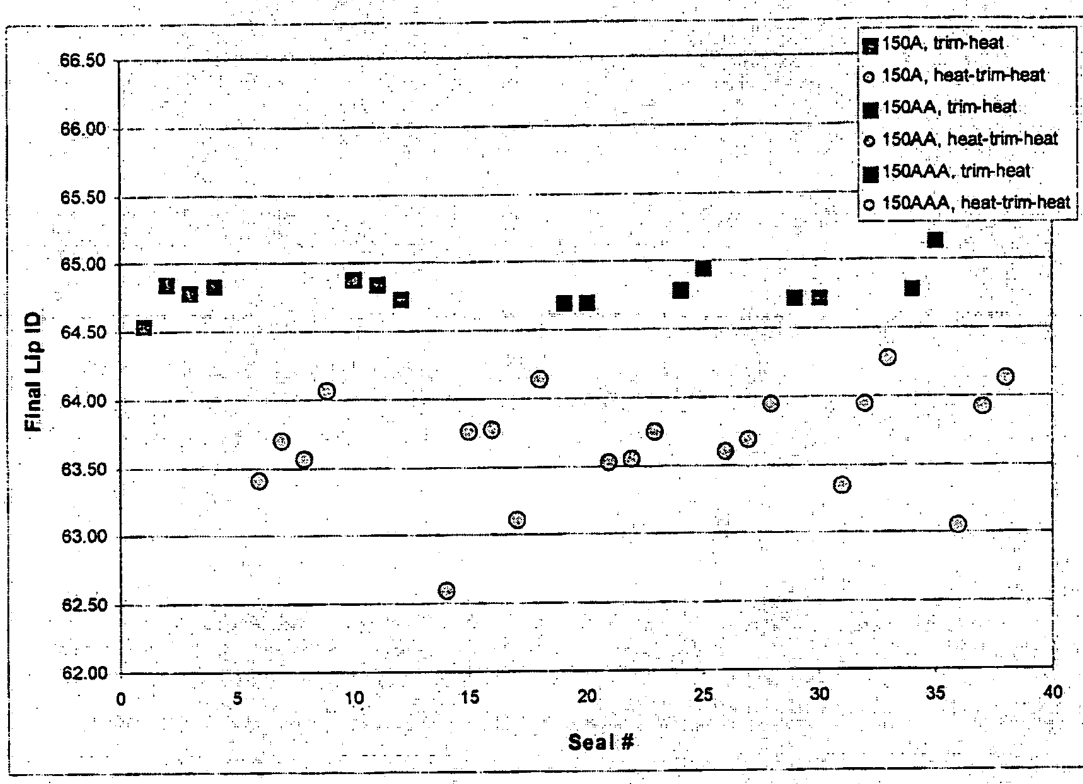


Figure 3: Final Lip ID (mm)

Two Omega test shafts are currently being made for testing of these seals. The shaft dimensions are 65.91 mm and 64.76 mm. The same leakage test cycle will be used for these seals as it was on the previous trials.

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FREUDENBERG-NOK
INVENTION DISCLOSURE FORM

Submitted By:_Edward Park_ Date:[redacted]

1. Short Title of the Invention:_TPE Based Dynamic Seal Development_& Est. Commercial Value, $_5,000,000______
2. Who first thought of the invention: Edward Park ______________
   When:[redacted]__ Where:_FNGP______________
3. The first written description/sketches and/or drawings of the invention were made on (attach copy)[redacted]________________________
4. The following records (attach if available) verify the conception date (letters, notes, reports):[redacted]FNGP Note Book #PCC550 (page 1);[redacted] FNGP Note Book #PCC550 (pages 2 and 4);[redacted]FNGP Note Book #PCC550 (pages 190 – 191);[redacted]FNGP Note Book #PCC550 (page 227); [redacted]FNGP Note Book #PCC550 (page 234);[redacted]FNGP Note Book #PCC550 (page 243) __
5. The invention was first disclosed to a person within FNGP:
   Date:________ To:____________________
6. First disclosure to a person outside of FNGP:
   Date:________ To:____________________
7. First Shipments (if any) of a product, composition, or process of the invention (attach copies)
   a. Sample(s) to:___________________ Date:__________
   b. Sale to:________________________ Date:__________
8. Brief description of your invention (attach additional sheets if necessary)

Modification of critical material properties required for dynamic seal performance and seal designs to accommodate unique characteristics of TPE materials are proposed to develop TPE based dynamic seals. Typically, two distinctive materials, cured elastomers and PTFE plastics, are widely used for dynamic seal applications. Material properties and commercial seal designs (Figures 1 and 2) for these two materials are quite different for dynamic seal applications. Since the properties of TPE materials are the mixture of elastomers and plastics properties, seal designs could be the combination of elastomers seal design and plastic (PTFE) seal design (Hybrid Seal Design). The initial choice of TPE material is FKM-TPV type TPE, which consists of a two-phase particulate morphology where FKM elastomer phase exists as discrete vulcanized particulates within a continuous FKM thermoplastic fluoroplastic matrix. To determine the required properties and the adequate design for FKM-TPV material, the differences in properties among elastomers, PTFE plastics and FKM-TPV materials should be considered. The examples of differences in properties and seal designs to be considered for FKM-TPV based dynamic seals are as follows, the ratio of recovery time to real time, the ratio of loss modulus to storage modulus, compression set, thermoplastic elastomeric nature of FKM-TPV, wettability with the lubricant in creation of the hydrodynamic film, material

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shrinkage, dimensional stability, radial spring force, lip location against the position of radial spring load, micro pumping effect, contact area and shape (leg length and contour) of lip, surface texture of lip (number of asperities), molecular orientation of FKM-TPV material due to mold flow design during injection molding operation, addition of inert fillers, application of various helix structure in the seal, etc. The wide spectrum of FKM-TPV materials can be obtained by varying the kind and ratio of FKM elastomers and fluoro-plastics, which make it possible to modify material properties to accommodate the effective dynamic seal designs. The desirable properties of TPE materials are as follows, the ratio of recovery time to real time (less than 1), the ratio of loss modulus to storage modulus (less than 0.1), low compression set at the elevated temperature, visco-elastic properties lean to elastic characteristic, high surface wetting capability with the lubricant in creation of the hydrodynamic film (low surface energy), pre heat-treatment to eliminate residual stress during thermoplastic processing, dimensional stability by adding fillers, and low shrinkage material. The seal design parameters should be modified to accommodate the unique properties of TPE materials are as follows, high radial spring force (followability improvement), lip location against the position of radial spring load (promote micro pumping effect), large contact area and shape (long leg length and contour) of lip, surface texture of lip (large number of asperities), molecular orientation of FKM-TPV material due to mold flow design during injection molding operation, addition of inert fillers (improve wear resistance after initial wear) and application of various helix structure in the seal (additional leakage protection). Based on the consideration of desirable properties and seal design parameters for TPE type materials, three hybrid seal designs are proposed for general TPE type materials (Figure 3). Initially, these designs are applied to FKM-TPV type TPE materials.

9. What advantages does your idea have (attach additional sheets if necessary)

The modification of critical material properties by developing a variety of formulations with the combinations of various FKM elastomers and fluoro-plastics and the modification of seal designs to accommodate the unique characteristics of TPE type materials provide the opportunity to develop TPE based dynamic seals. FKM-TPV type TPE materials under development at FNGP are the initial targets for this concept.

Signatures of Inventor(s)		Witness Signature(s): The above was read and understood by me	
Edward H. Park__	[redacted] Date	____________________	__________ Date
Vahidin A. Alajbegovic__________	Date	____________________	__________ Date

Alex Berdichevsky__ ___________ ___________________ ___________

Date Date

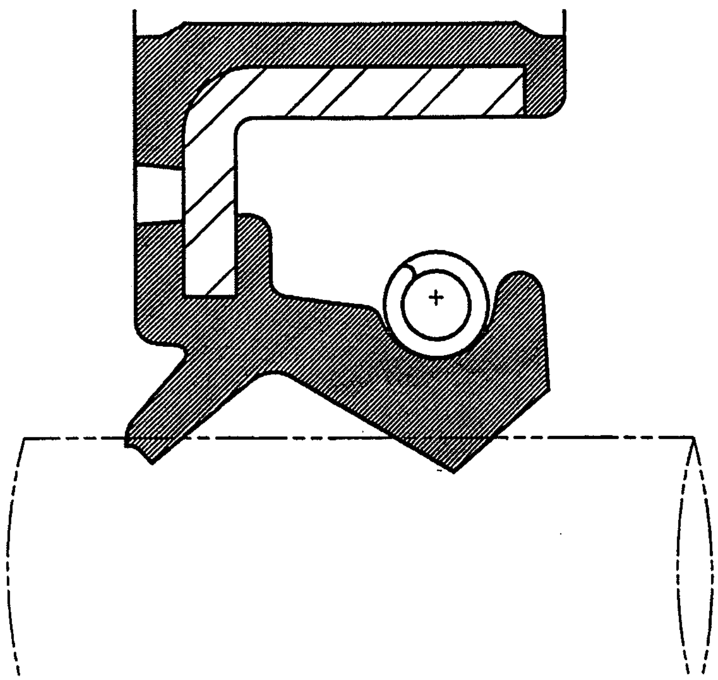

Figure 1. Typical Commercial Rubber (Elastomer) Dynamic Seal

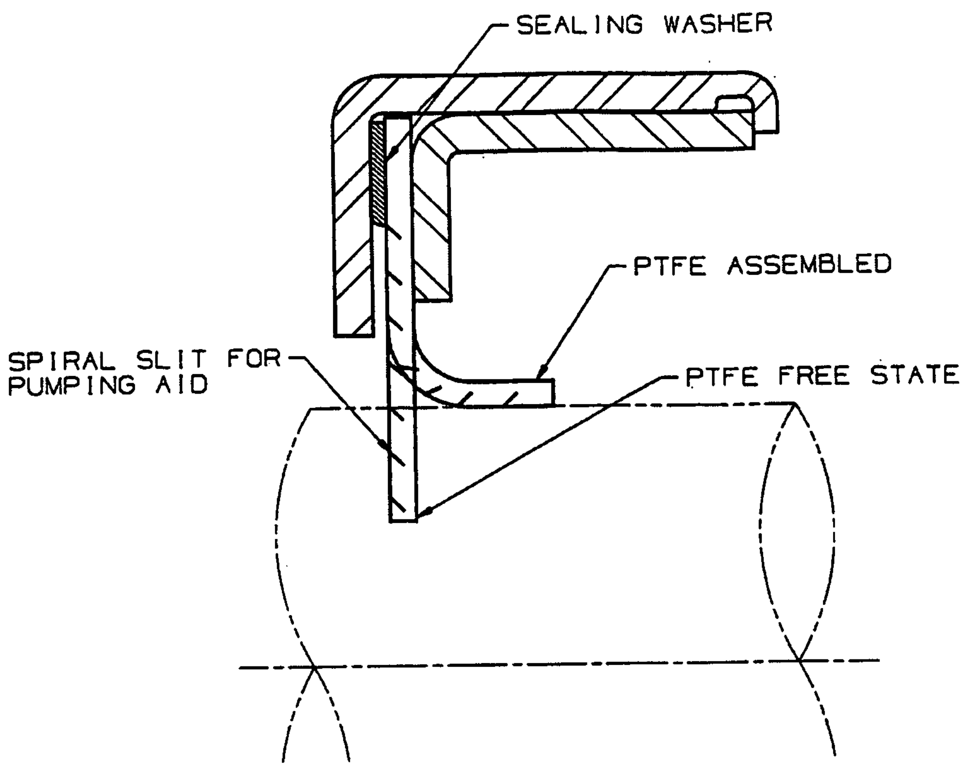

Figure 2. Typical Commercial PTFE Dynamic Seal

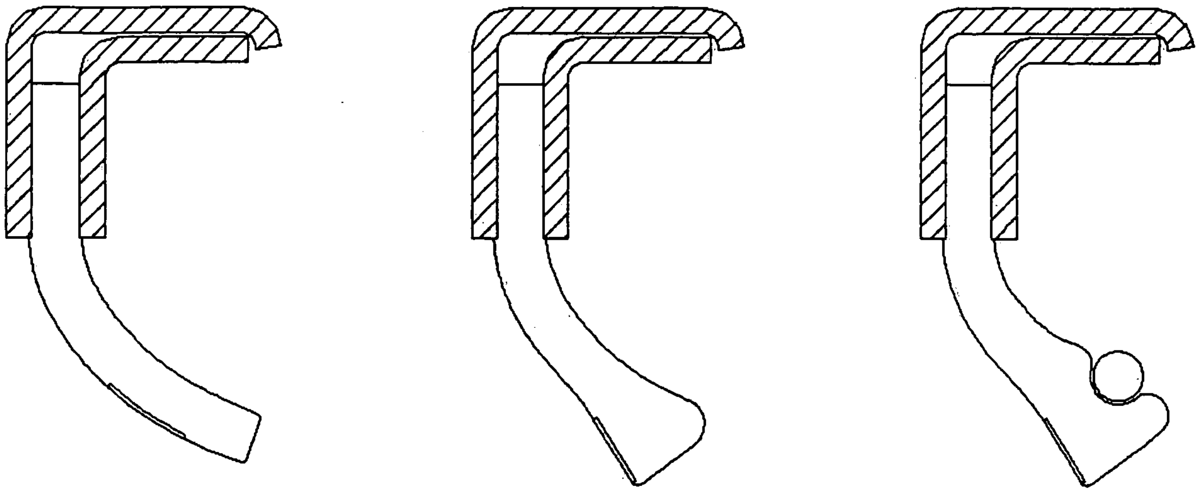

Figure 3. Proposed Hybrid Seal Designs for TPE (FKM-TPV) type Materials